Air density dependence of the response of the PTW SourceCheck 4π ionization chamber for Pd-103 brachytherapy sources

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Introduction

Radionuclides emitting low energy photons are usually used for the implementation of brachytherapy techniques. Air vented chambers are commonly used to assess air kerma strengh of these sources. The signal produced is supposed to be proportional to the air density within the chamber and, therefore a density-independent air kerma strengh is obtained when the measurement is corrected using the usual temperature and pressure correction factor. However, some well-type ionization chambers, especially when used for assessing brachytherapy sources including low-energy radionuclides such as 103Pd, 125I or 131Cs, do not fulfill that condition and a residual density dependence still remains after correction. The purpose of this work is to analyze the response of the PTW SourceCheck 4π ionization chamber to air density changes for Pd-103 sources, for which has not been characterized to date and to perform an additional study for the Standard Imaging HDR1000 Plus chamber, already characterized by other authors [1].

Material and methods

The ionization chambers used were three PTW SourceCheck 4π TW33005 (with a PTW Unidos electrometer), and a Standard Imaging HDR1000Plus (with a Standard Imaging MAX4000 electrometer).
To study the air density dependence of the response of the ionization chambers, each one was introduced in a pressure chamber equipped with a thermometer-hygrometer-barometer THB 40 (PCE Instruments). Pressure changes were produced by a vacuum pump. The sources were four TheraSeed® 200 Palladium-103 seeds (Theragenics Corporation). For each ionization chamber, two series of measurements were made along a pressure range from 666.6 to 1039.9 hPa (500 to 780 mmHg) in steps of ≈ 40 hPa taking three measurements for each pressure value. Each measurement was taken in a time interval of about 1 min and was obtained after reaching the equilibrium between the pressures inside and outside the ionization chamber. Fig. 1 shows a schematic view of the experimental setup.

The measurements obtained can be written as

$$M_{Corr} = g_0(\rho) g_1(\rho) M_{raw} \quad (1)$$

being $g_0(\rho)$ the usual temperature-pressure factor and $g_1(\rho)$ an additional factor. The product of these two factors can be written as

$$g_0(\rho) g_1(\rho) = \left(\frac{\rho}{\rho_0}\right)^{-u} \quad (2)$$

being ρ and ρ_0 the air density under actual and standard conditions, respectively; and u the fit parameter.

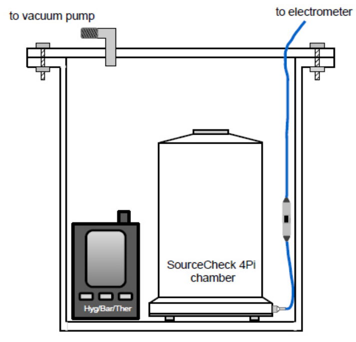

Figure 1. Experimental setup

To study the factor $g_1(\rho)$, we have plotted the experimental data normalized with respect to the reference value under normal conditions of temperature and pressure, M_0:

$$\overline{M}(\rho) = g_0(\rho) M_{raw} / M_0 \quad (3)$$

To study the influence of the geometry and the number of seeds used, an adapter with four seeds separated from each other by seed spacers commonly used in prostate implants was employed.

Results and discussion

In Figure 2 the results of the measurements for the Pd-103 made in the pressurized chamber are shown for different densities once they have been normalized and corrected by the pressure-temperature usual factor for the three SourceCheck 4π ionization chambers (colored circles), one HDR 1000 Plus chamber (squares) considered in the present work and the results of Griffin et al. [1]. The lines represent the fit of Eq. (3) to the data. Uncertainties are shown with a coverage factor k = 2. Figure 3 shows (red circles) the results of the measurements for one of the SourceCheck 4π chambers when four seeds are used simultaneously.

As can be seen, in the case of Pd-103 sources, there is a coincidence, within the uncertainties, of the responses of the three SourceCheck 4π chambers. The air density dependence for both types of chambers, SourceCheck 4π and HDR1000 follows the same trend, and can be described by a potential model in contrast with the linear dependence which shows in the case of I-125 sources [2].

A value of u=0.533±0.002 (k=2) can be adopted in equation (2) to calculate the air density correction for the SourceCheck 4π chamber. For the HDR1000 Plus chamber, a value of u=0.431±0.003 (k=2) was obtained. A reanalysis of Griffin et al. (2005) data produced u=0.443 for the HDR1000 Plus. Finally, as can be seen in Figure 3 there is no influence of the number of seeds simultaneously measured on the air density dependence.

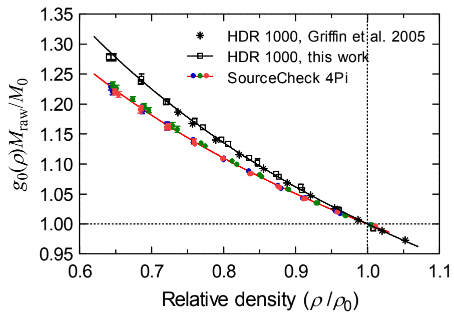

Figure 2. Normalized measured values, for Pd-103 source, corrected by the usual density factor, $g_1(\rho)$, as a function of the density ratio ρ/ρ_0 for the three SourceCheck 4Pi ionization chambers (colored circles) and one HDR 1000 Plus chamber (squares) considered in the present work. The lines represent the fit of Eq. (3) to the data. Uncertainties are shown with a coverage factor k = 2.

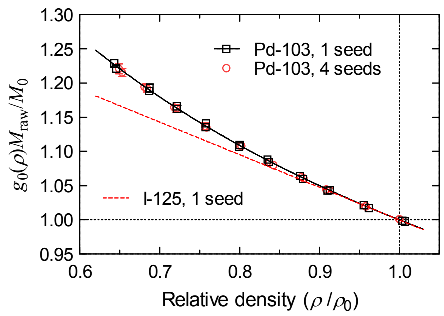

Figure 3. Normalized measured values, for Pd-103 source, corrected by the usual density factor, $g_1(\rho)$, as a function of the density ratio ρ/ρ_0 for one of SourceCheck chamber when one (squares) o four seeds (red circles) are used. The dependence of this chamber for I-125 seeds is also shown (red dashed line). The Uncertainties are shown with a coverage factor k = 2.

Conclusions

Once the standard pressure and temperature factor was applied, PTW SourceCheck 4π chambers show a residual dependence on the air density for Pd-103 sources which is better described by a potential function rather than by a linear one, on the contrary to what happens when using I-125 sources. The reason for these differences is currently being investigated using Monte Carlo methods.

Acknowledgments

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References

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